

CReSIS OIB Planning Meeting

June 29 – July 1, 2010

Prasad Gogineni, Chris Allen, Carl Leuschen,
John Paden, and William Blake

NATIONAL SCIENCE FOUNDATION :: KANSAS TECHNOLOGY ENTERPRISE CORPORATION :: NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

The University of Kansas | The Ohio State University | Pennsylvania State University
The University of Maine | Elizabeth City State University | Haskell Indian Nations University

Centre for Polar Observation and Modelling | University of Copenhagen
Technical University of Denmark | Antarctic Climate & Ecosystems CRC



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People

Aerospace:

**Rick Hale, Emily Arnold, John Hunter,
Wanbo Liu**

Radar System:

**Prasad Gogineni, Chris Allen, Carl
Leuschen, Sarah Seguin, Fernando
Rodriguez-Morales, John Ledford, Lei Shi,
Ben Panzer, Aqsa Patel, Kyle Byers, Reid
Crowe, Dennis Sundermeyer**

Data Processing:

**Ken Jezek, John Paden, Lei Shi, William
Blake, Keith Lehigh, Josh Meisel,
Deepanathan Dhanasekaran**



Sensors

Instrument	Measurement	Frequency (Bandwidth)	Platform	Deployment
MCoRDS	<ul style="list-style-type: none"> • Ice Thickness • Bed Characteristics • Bed Imaging • Internal Layering 	195 MHz (30 MHz)	<ul style="list-style-type: none"> • DC-8 • P-3 • Twin Otter 	<ul style="list-style-type: none"> • Fall 2009 (DC-8) • Spring 2010 (DC-8 and P-3)
Accumulation	<ul style="list-style-type: none"> • Internal Layering 	750 MHz (300 MHz)	<ul style="list-style-type: none"> • P-3 • Twin Otter 	<ul style="list-style-type: none"> • Spring 2010 (P-3)
Snow Radar	<ul style="list-style-type: none"> • Snow Cover • Internal Layering • Topography 	4.5 MHz (4 MHz)	<ul style="list-style-type: none"> • DC-8 • P-3 	<ul style="list-style-type: none"> • Spring 2009 (P-3) • Fall 2009 (DC-8) • Spring 2010 (DC-8 and P-3)
Ku-Band	<ul style="list-style-type: none"> • Snow Cover • Topography 	14 MHz (4 MHz)	<ul style="list-style-type: none"> • DC-8 • P-3 • Twin Otter 	<ul style="list-style-type: none"> • Fall 2009 (DC-8) • Spring 2010 (DC-8 and P-3)
TIDSOR	<ul style="list-style-type: none"> • Ice Thickness 	13.5 MHz (1 MHz)	<ul style="list-style-type: none"> • Surface 	<ul style="list-style-type: none"> • N/A



Presentations

- Snow and Ku-Band Status and Results
- **MCoRDS Status and Results**
- MCoRDS Processing
- FMCW Processing
- MCoRDS Tomography Results
- Dual-Frequency HF Radar Sounder for Surface and Airborne Measurements



Radar depth sounding of polar ice

Multichannel Coherent Radar Depth Sounder (MCoRDS)

Platform: DC-8

Peak transmit power: 550 W

Center frequency: 195 MHz

Waveform duration: 1, 10, or 30 μ s

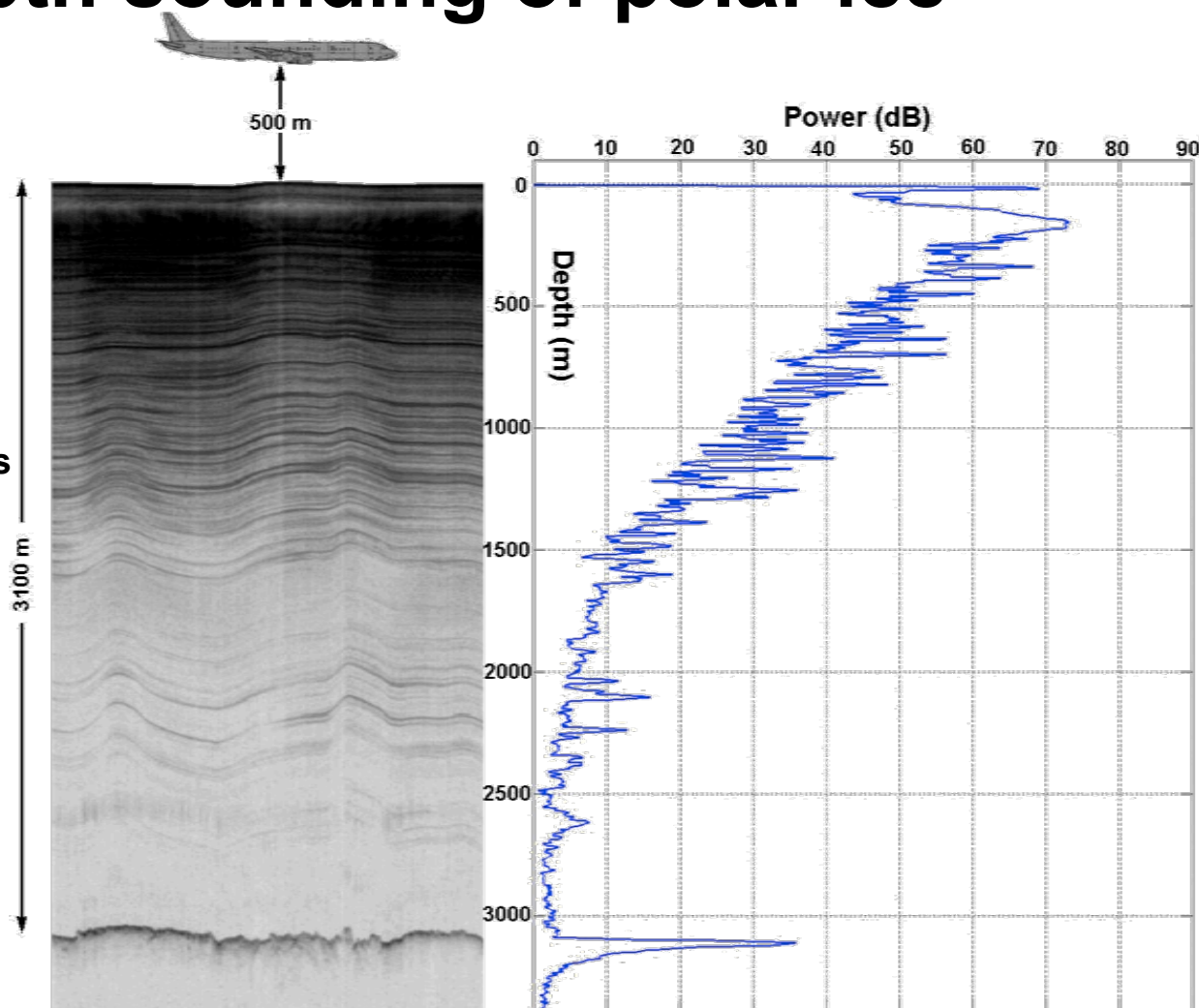
Waveform bandwidth: 10 or 30 MHz

PRF: 9 kHz

Rx noise figure: 5 dB

Tx/Rx antenna array: 5 elements

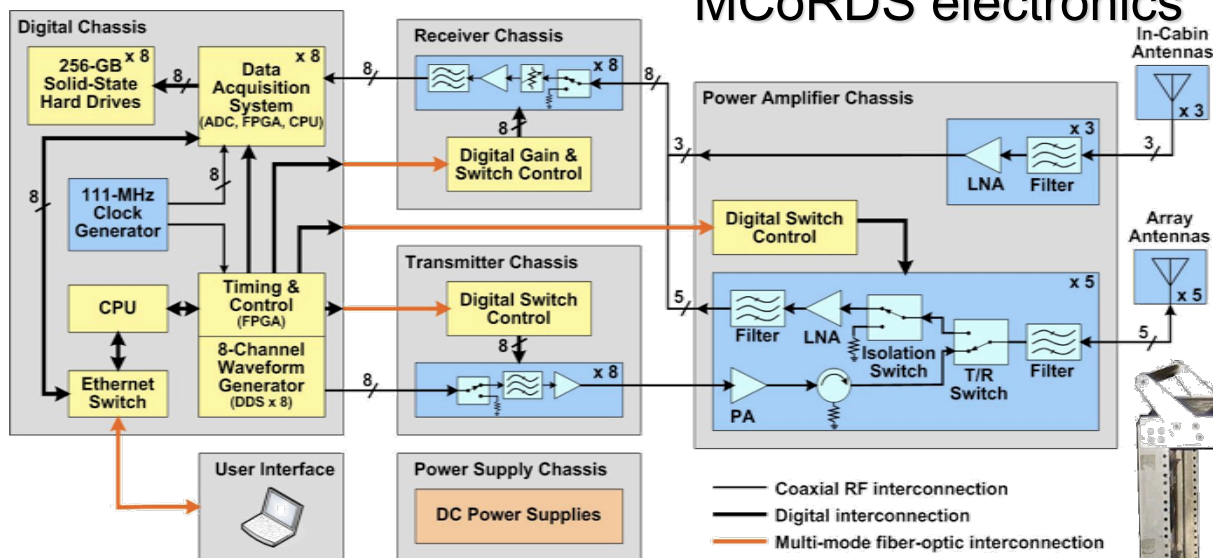
Element type: $\lambda/4$ dipole



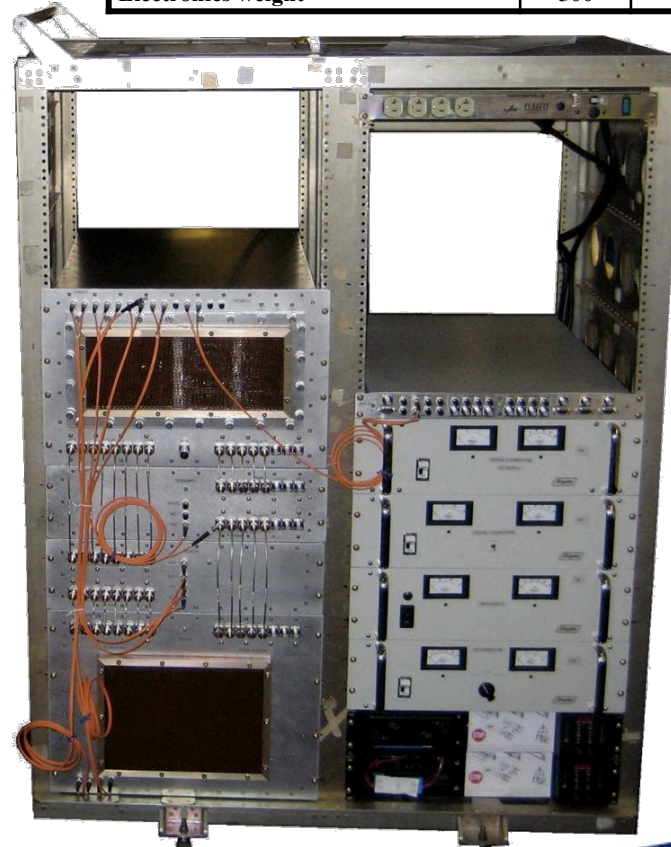
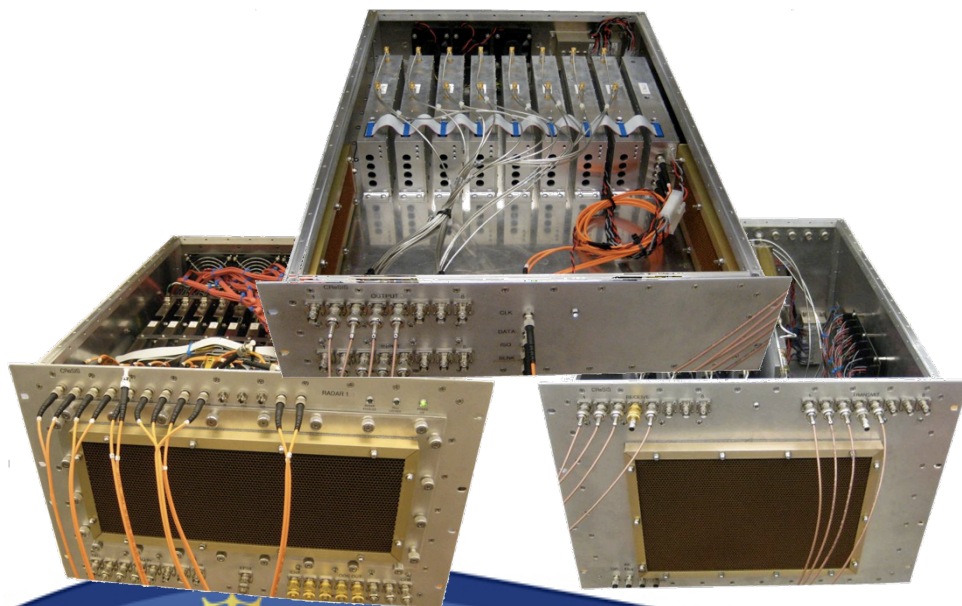
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Sensor hardware for OIB DC-8

MCoRDS electronics

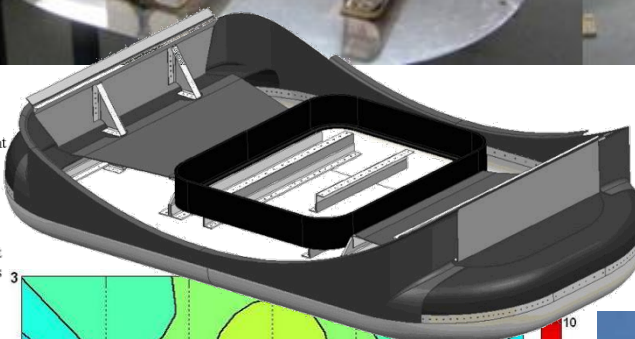
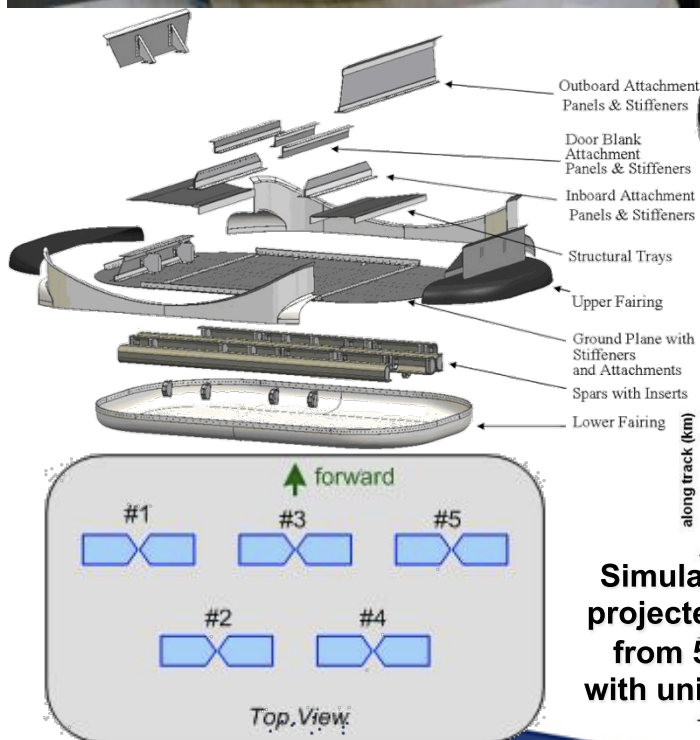


Parameter	Value	Units
Hardware presumps	16	
Digitizer sample rate (per channel)	111	MSa/s
Receive vector length	10,000	samples
Recording data rate (per channel)	21	MB/s
Number of receive channels	8	
Solid-state drive capacity (per channel)	256	GB
On-board data storage capacity	2	TB
Electronics weight	500	lbs



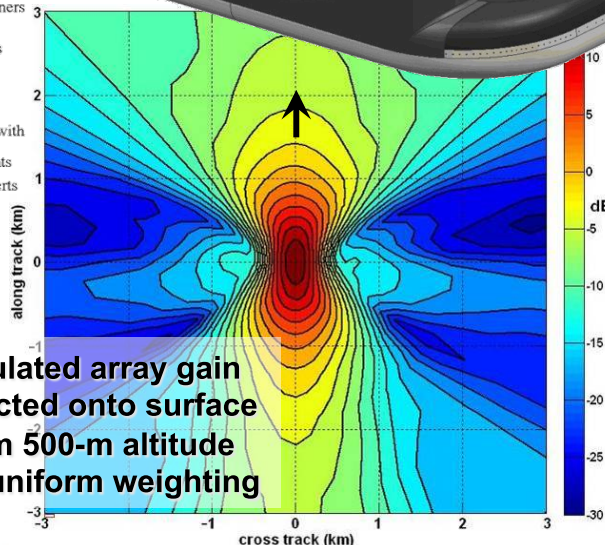
Sensor hardware for OIB DC-8

MCoRDS antenna array and fairing hardware



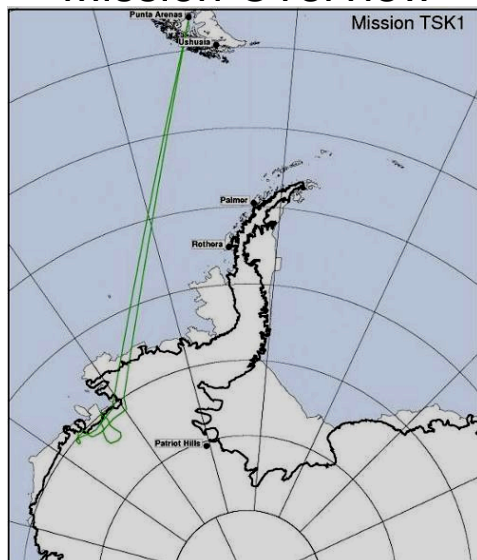
5-element staggered collinear array
Ground plane dimensions: 2.5 x 4.5 m
Assembled weight (est.): 425 lbs
Added drag (simulated): 1.3%

Simulated array gain
projected onto surface
from 500-m altitude
with uniform weighting

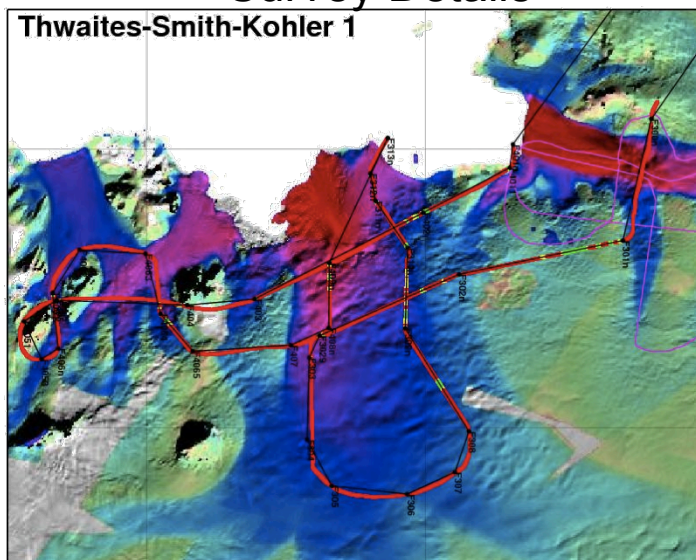


Example data from 02-Nov-09 Flight #12 TSK1 Mission

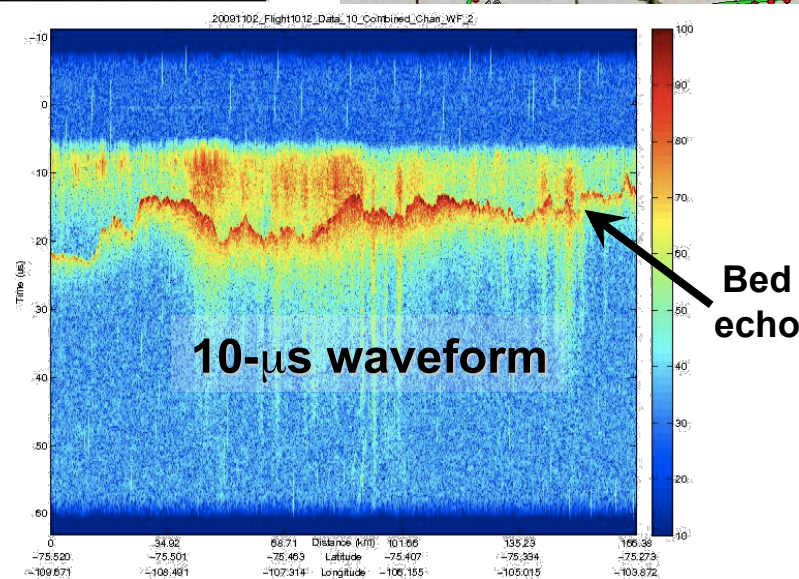
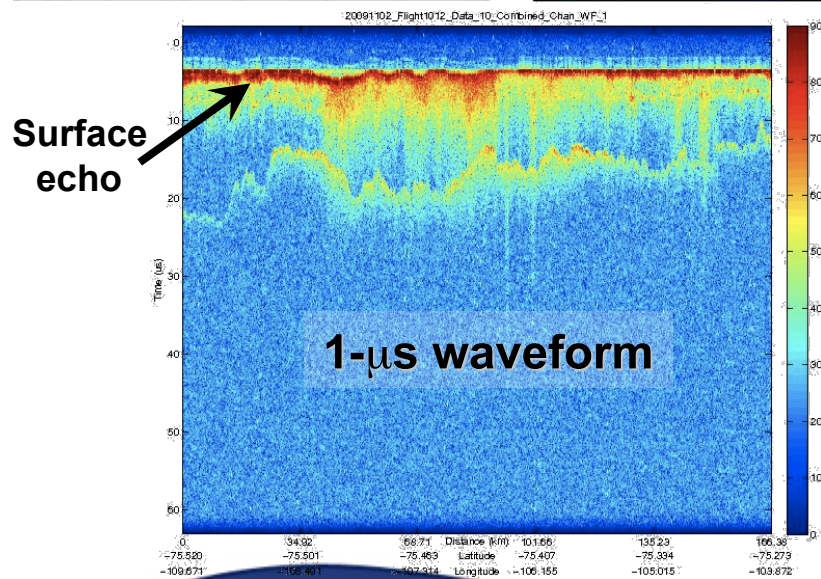
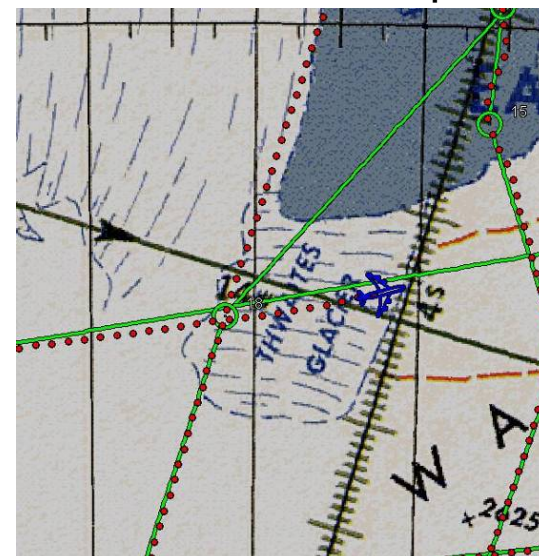
Mission Overview



Survey Details



Falcon View Map



MCoRDS data summary and status

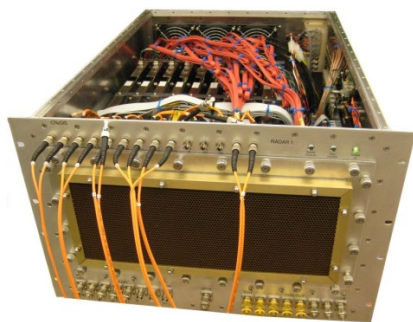
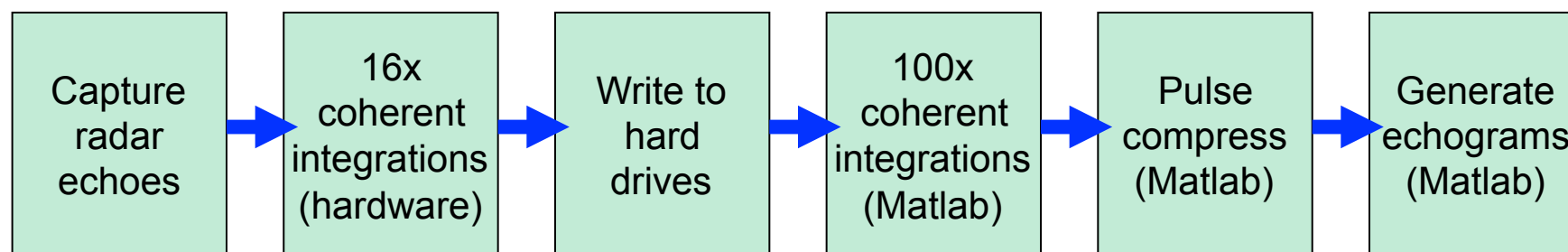
Flight #	Date	Survey Area	Data Set Volume (GB)
1	10/16/2009	GETZ	1256
2	10/18/2009	TSK2	1230
3	10/20/2009	Pine Island (High Alt)	1016
4	10/21/2009	Sealce2	
5	10/24/2009	Sealce1	
6	10/25/2009	86° Arc (High Alt)	1280
7	10/27/2009	PIG2	1684
8	10/28/2009	TSK3	616
9	10/29/2009	PIG1	1416
10	10/30/2009	Sealce3	
11	10/31/2009	PEN2	1360
12	11/2/2009	TSK1	1216
13	11/3/2009	PEN1	1280
14	11/4/2009	PEN3	2000
15	11/5/2009	Peninsula (High Alt)	1624
16	11/7/2009	PIG3	1392
17	11/9/2009	PIG4	1184
18	11/12/2009	ABBOTT	980
19	11/15/2009	PEN4	1232
20	11/16/2009	PEN5	1552
21	11/21/2009	TSK4	912

PIG: Pine Island; **TSK:** Thwaites, Smith, Kohler

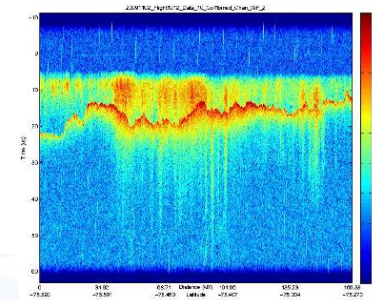
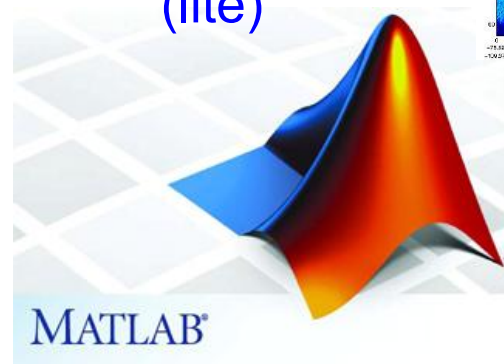
All low-altitude data sets processed using basic algorithm, surface and bed echoes hand picked, and resulting thickness values have been posted. Data will be reprocessed using f-k process and more automated bed-picking process.



MCoRDS – data processing



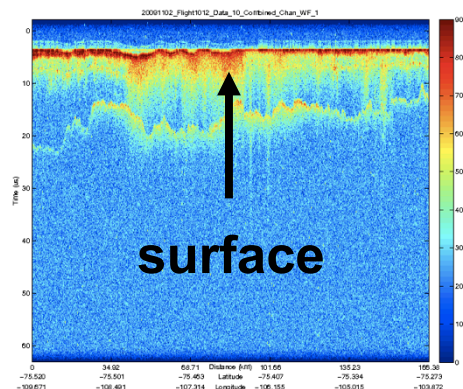
CSARP
(lite)



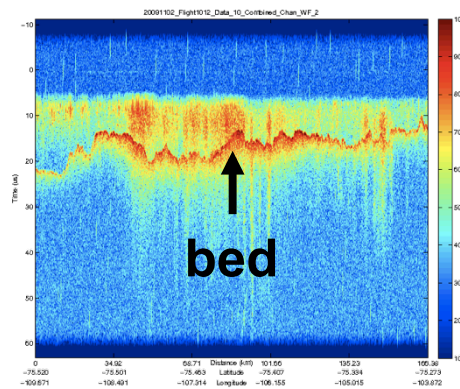
CRISIS

MCoRDS – data processing

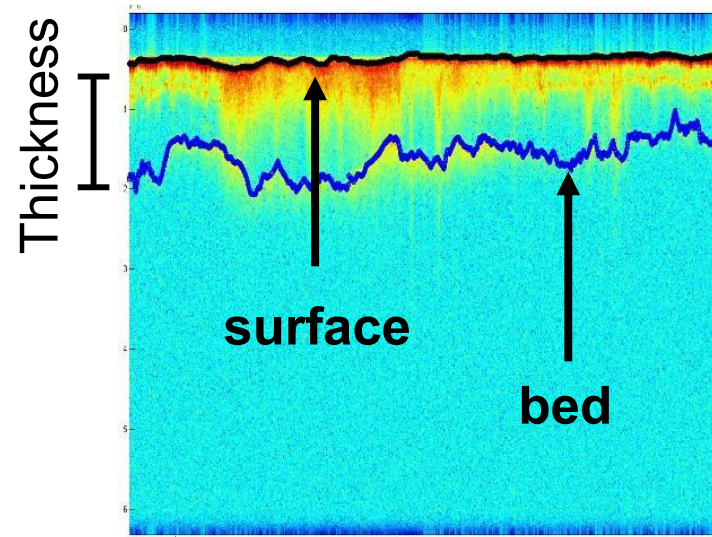
Waveform 1



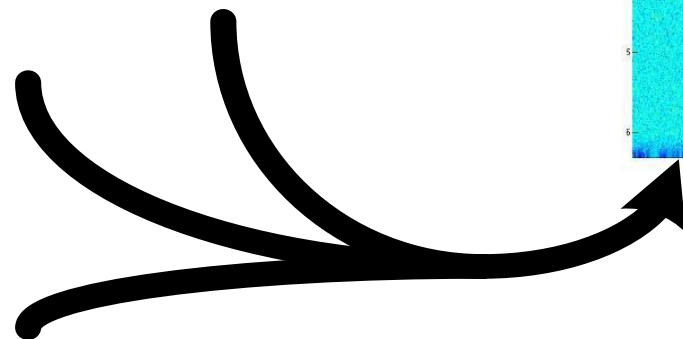
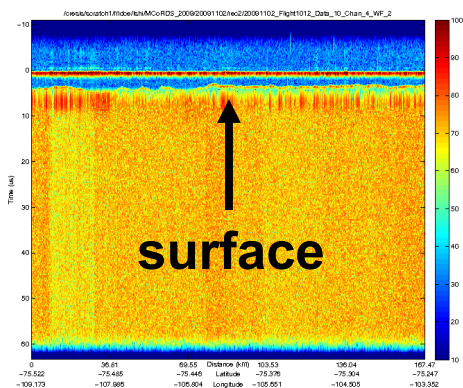
Waveform 2



Layer Tracing

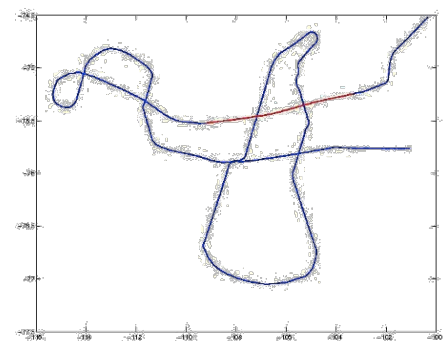


or
EMI Channel



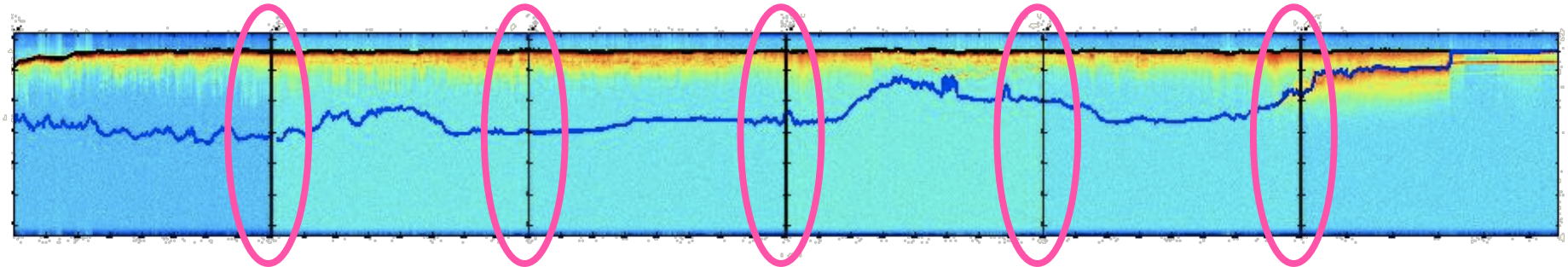
Flight Path

Echogram represented in red



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Continuity Check



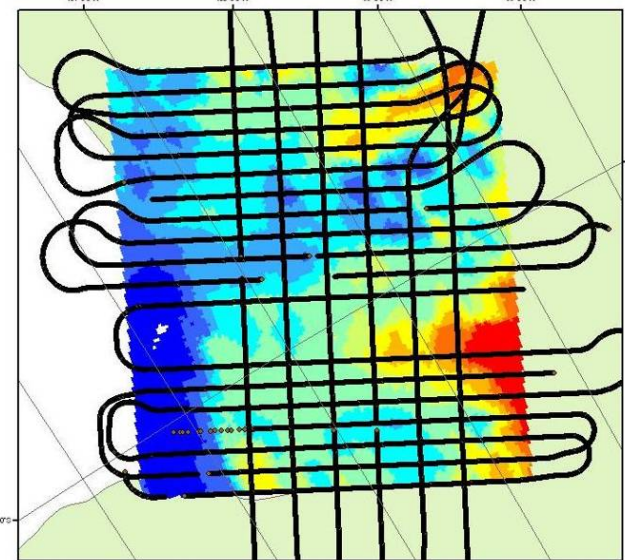
```

20091102_Flight1012_Data_10.txt - WordPad
File Edit View Insert Format Help
Counter New 10 Western
1 Time, Lat, Lon, Longitude, Elevation, Surface, Bottom, Thickness
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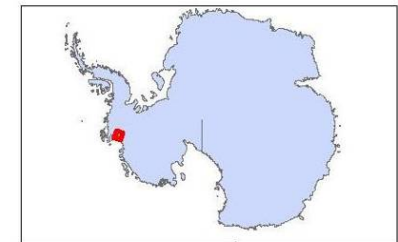
Generate Text (.txt) files with:

- Time
- Latitude
- Longitude
- Thickness

Pine Island Ice Thickness



Ice Thickness



Disregard:
Elevation, Surface, Bottom



Crossover areas

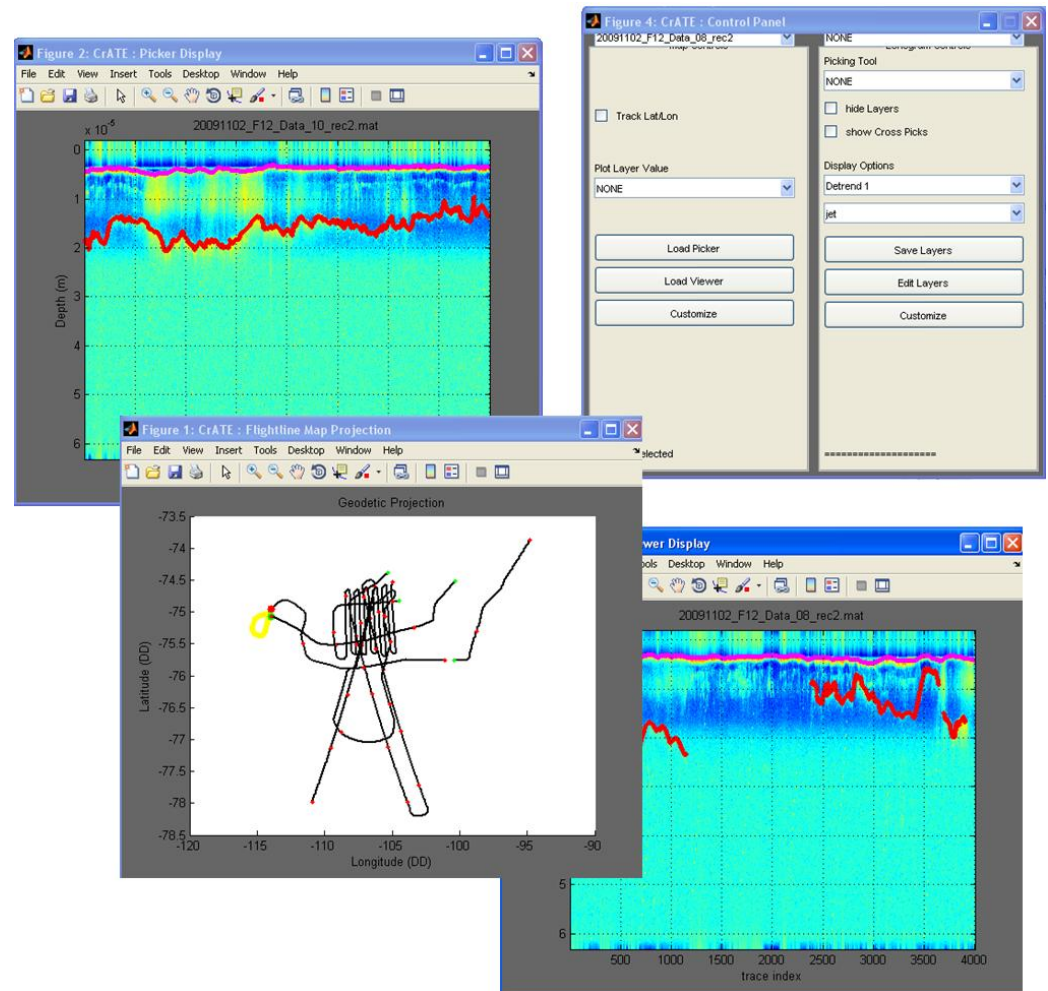
Newly developed layer tracing software “Crate 4”

Load and compare two echograms (across multiple missions if needed)

Fix a crossover inconsistency on the spot

A separate crossover error detection program is being developed.

Ohio State University using ArcGIS for detecting inconsistencies in processed data



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Crossover areas

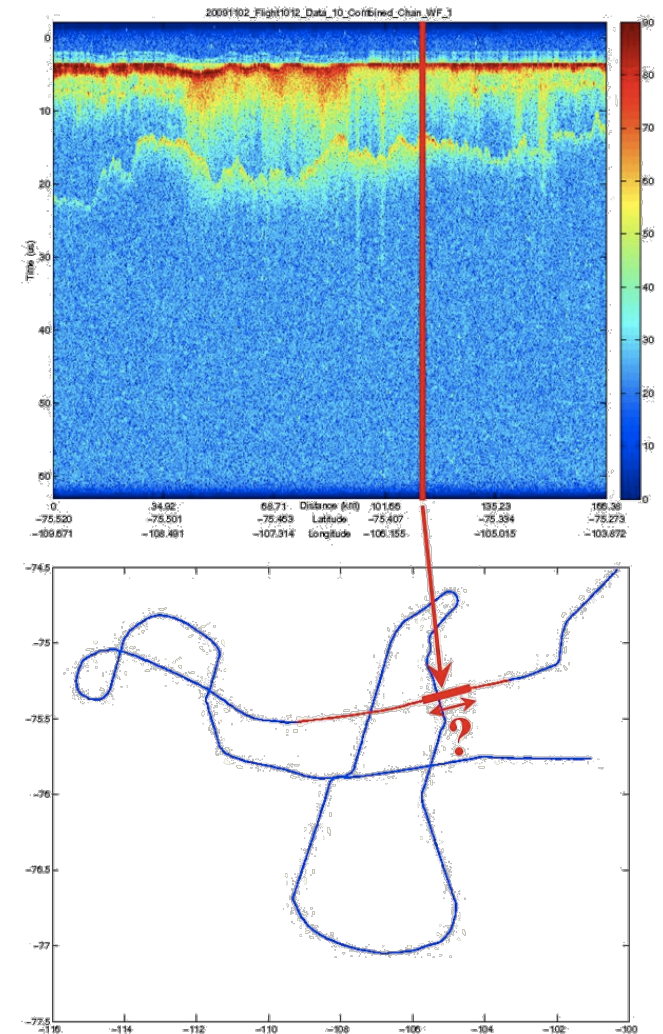
Variable time-stamp latency (about 2 seconds)
contributes to crossover discrepancies

Multiple potential causes for this latency (in-flight
data server, radar time-stamp manager)

Net result is location uncertainty along flight
path which contributes to crossover
discrepancies in measured ice thickness

Short-term solution, attempt to remove this
unknown latency

Long-term solution may involve direct access
to GPS receiver output and refined radar
time-stamp management



Data acquisition issues

Flight 7 (10/27/2009) PIG and Flight 8 (10/28/2009) TSK

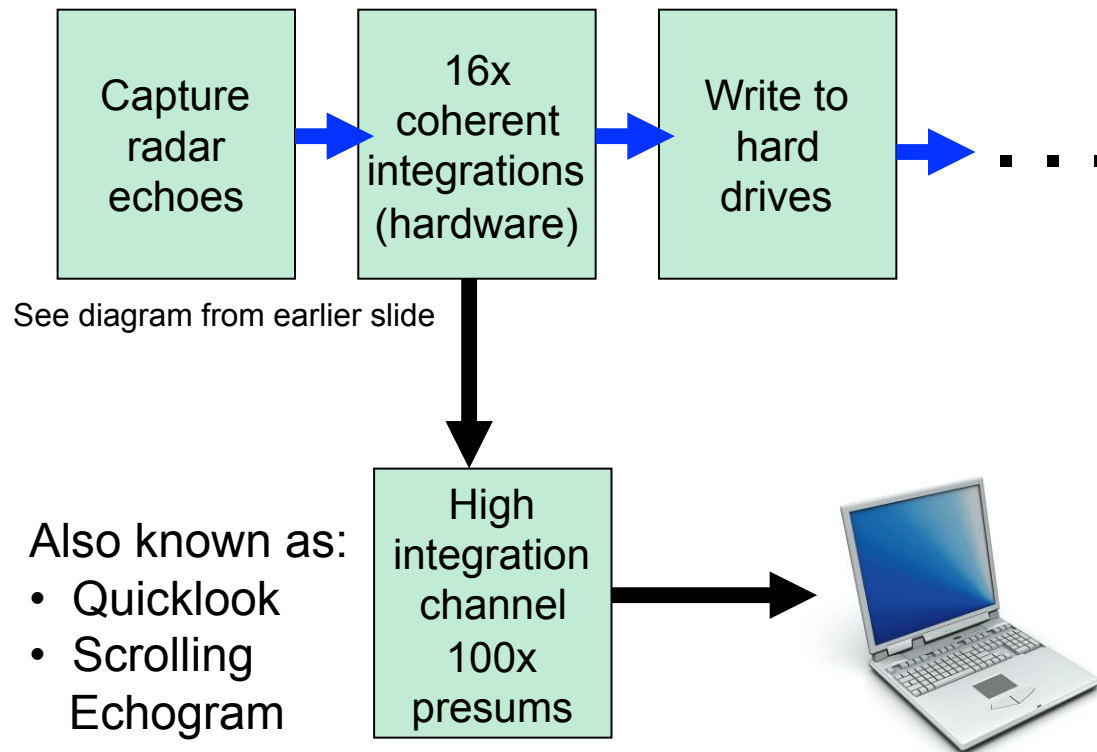
<u>Radar Configuration File</u>		<u>Radar Controller Error</u>	<u>Effects of Error</u>
WAVEFORM 1			
Waveform Duration	10us	→ Used for Waveform 1	Data rates were too high for recording
Record Length	70us	→ These times used for	
Record Start	23us	→ both waveforms (1 and 2).	
WAVEFORM 2			Recording began too late for surface returns to be captured
Waveform Duration	1us	→ Used for Waveform 2	Result – no surface echo for ice thickness measurement
Record Length	25us	→ Not used	
Record Start	9us	→	



Data acquisition issues

Flight 7 (10/27/2009) and 8 (10/28/2009)

High Integration
Channel Data

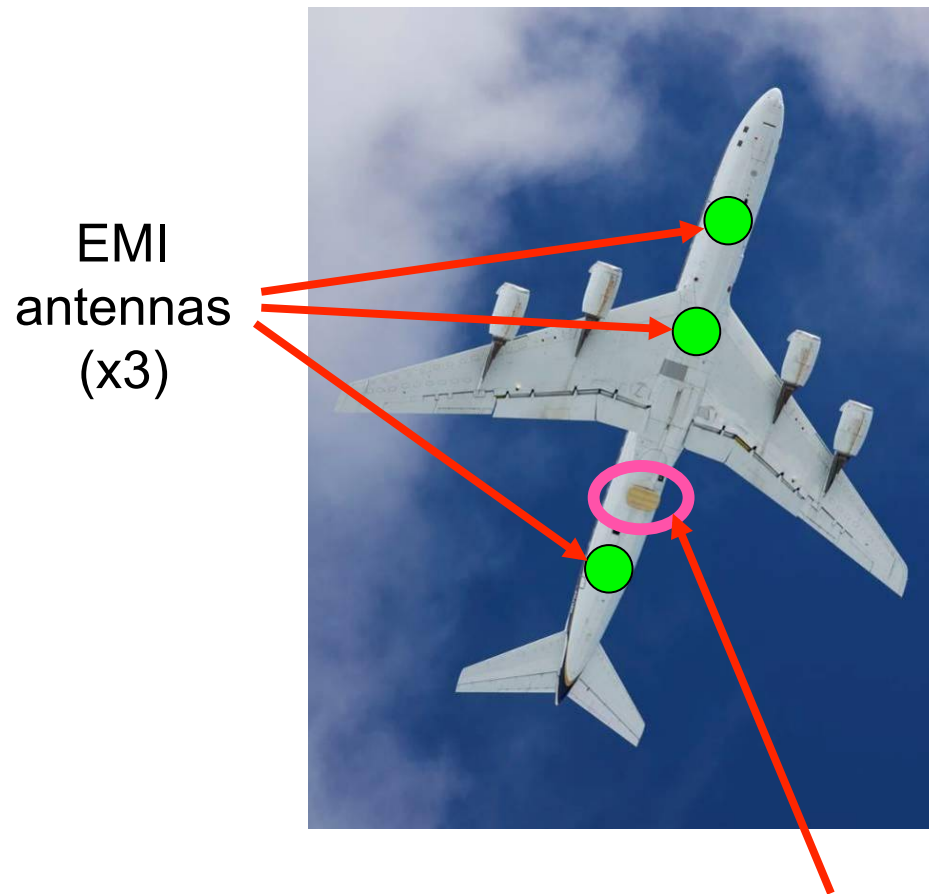


- Sampled every 1 / 62.5 hard drive writes
- Stored on laptop computer
- **Useable data recorded**
- **No surface echo** (uses same record window)



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EMI vs radar antennas



EMI-monitoring antennas
located inside cabin

EMI channel data often
used for surface tracing

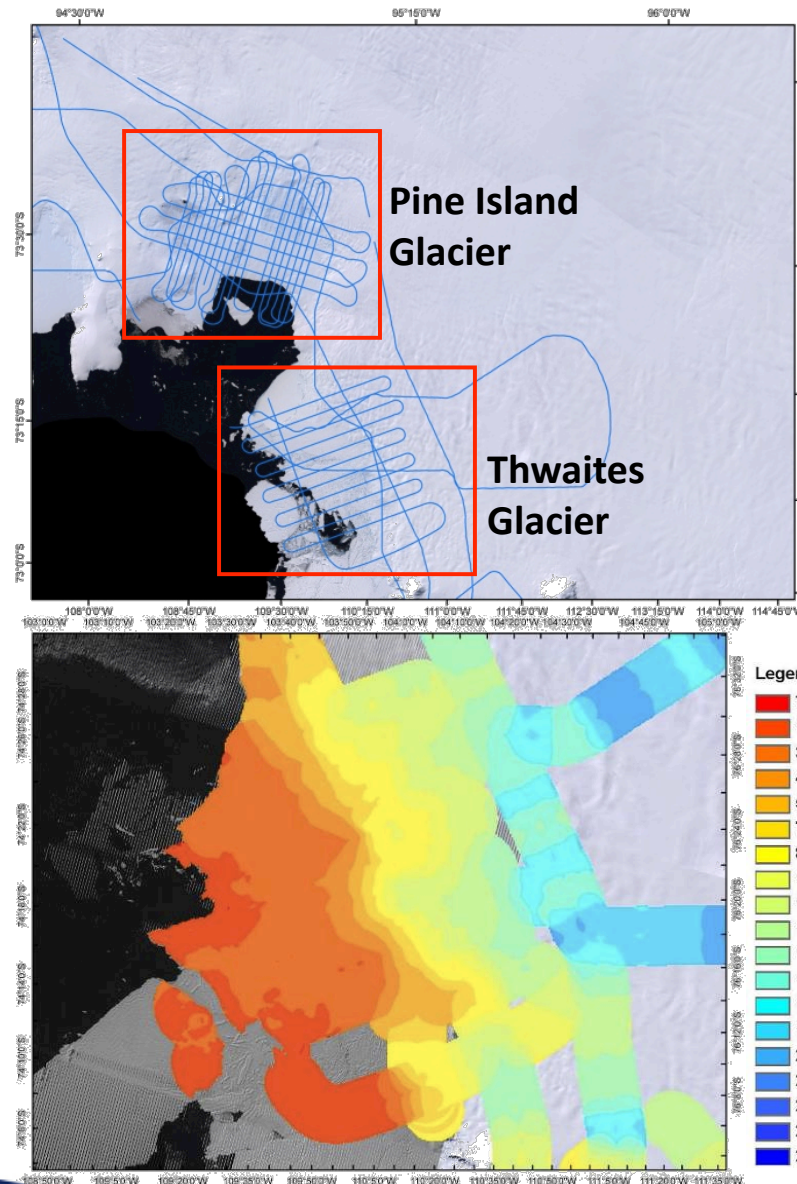
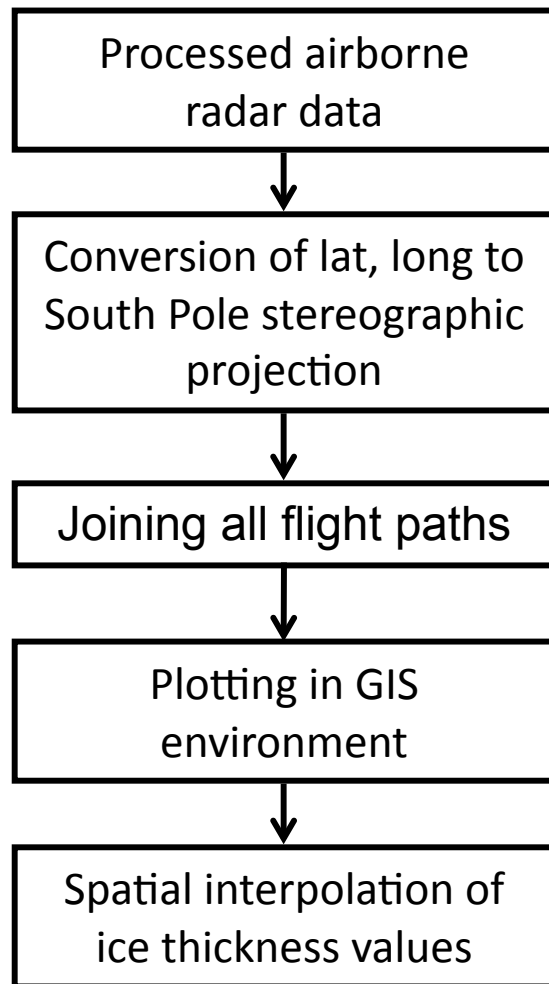
Radar channel data used
for bed tracing

Cable lengths are different

Ice thickness adjustments
made to reflect the
difference in cable
lengths.



Process for ice thickness DEM generation



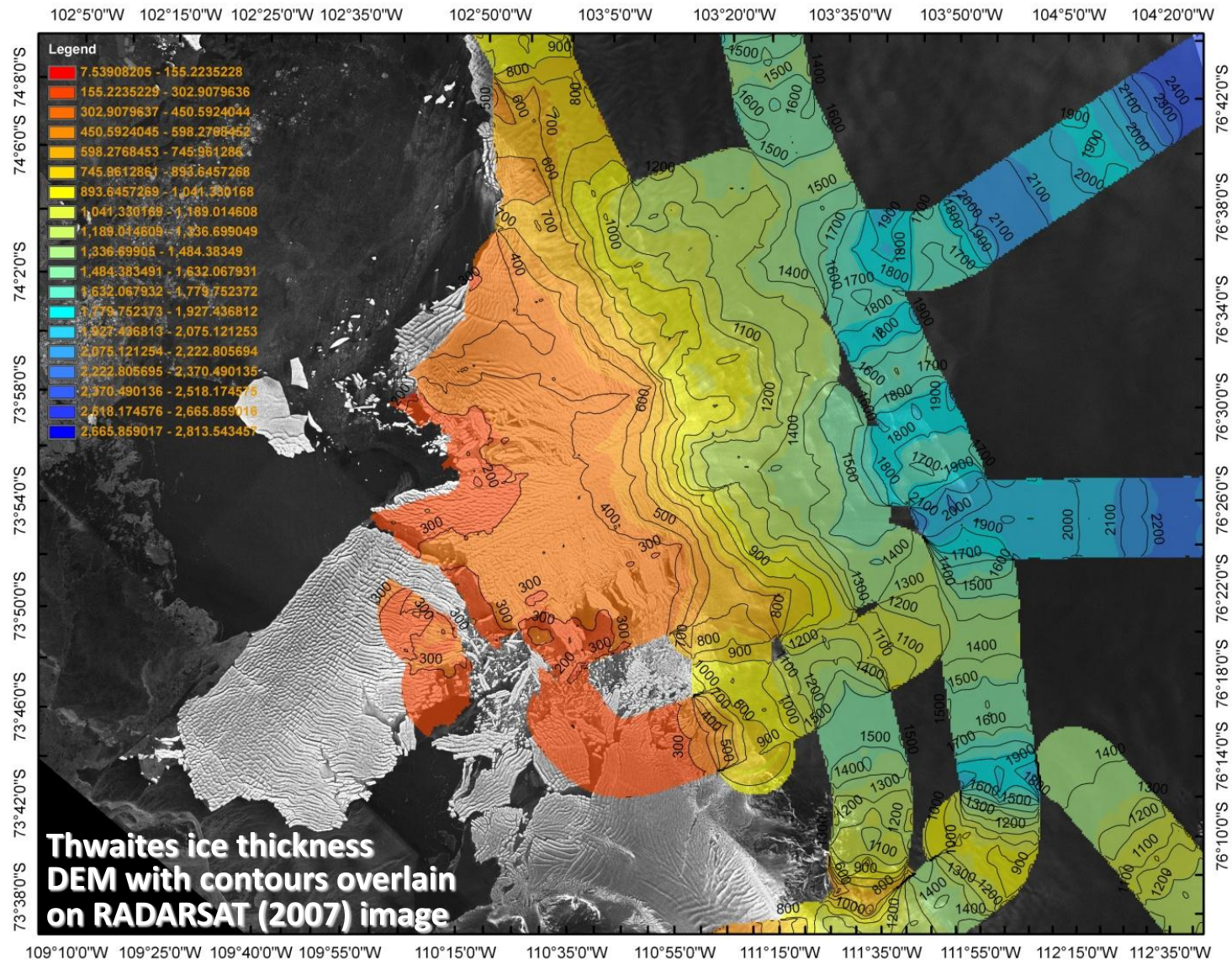
Flight path over Pine Island and Thwaites Glaciers

Linear IDW interpolated (10-km search radius) ice thickness DEM over Thwaites Glacier

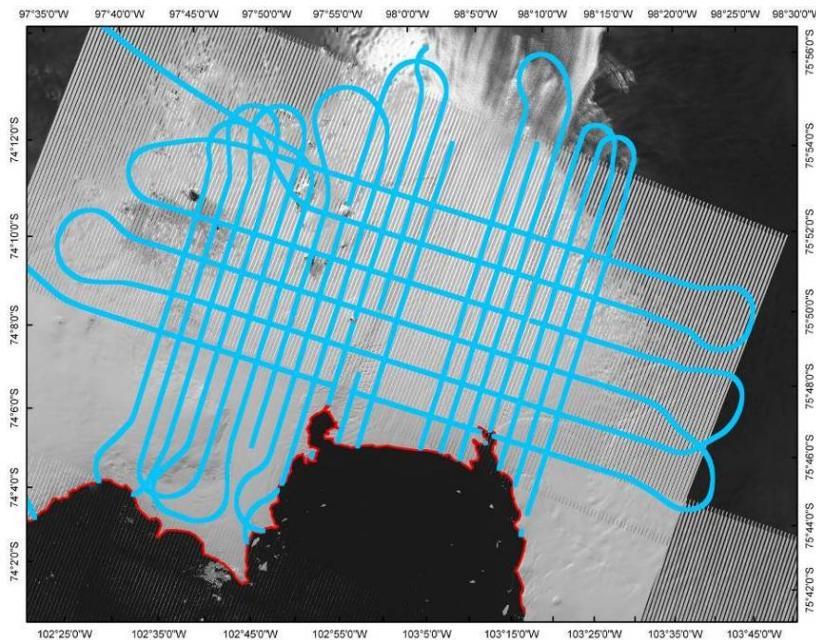
IDW = inverse distance weighted



Thwaites ice thickness DEM



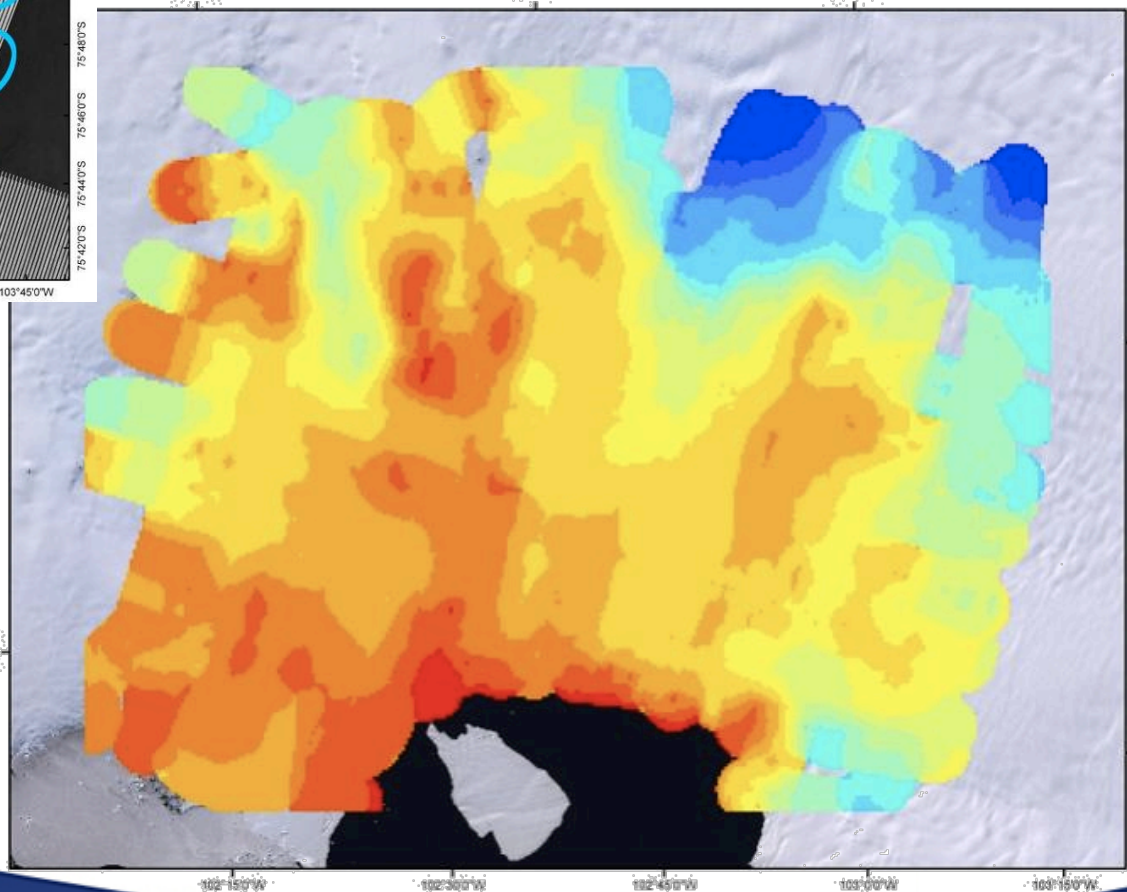
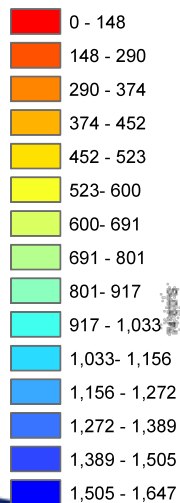
Pine Island ice thickness DEM



Flight path over Pine Island Glacier

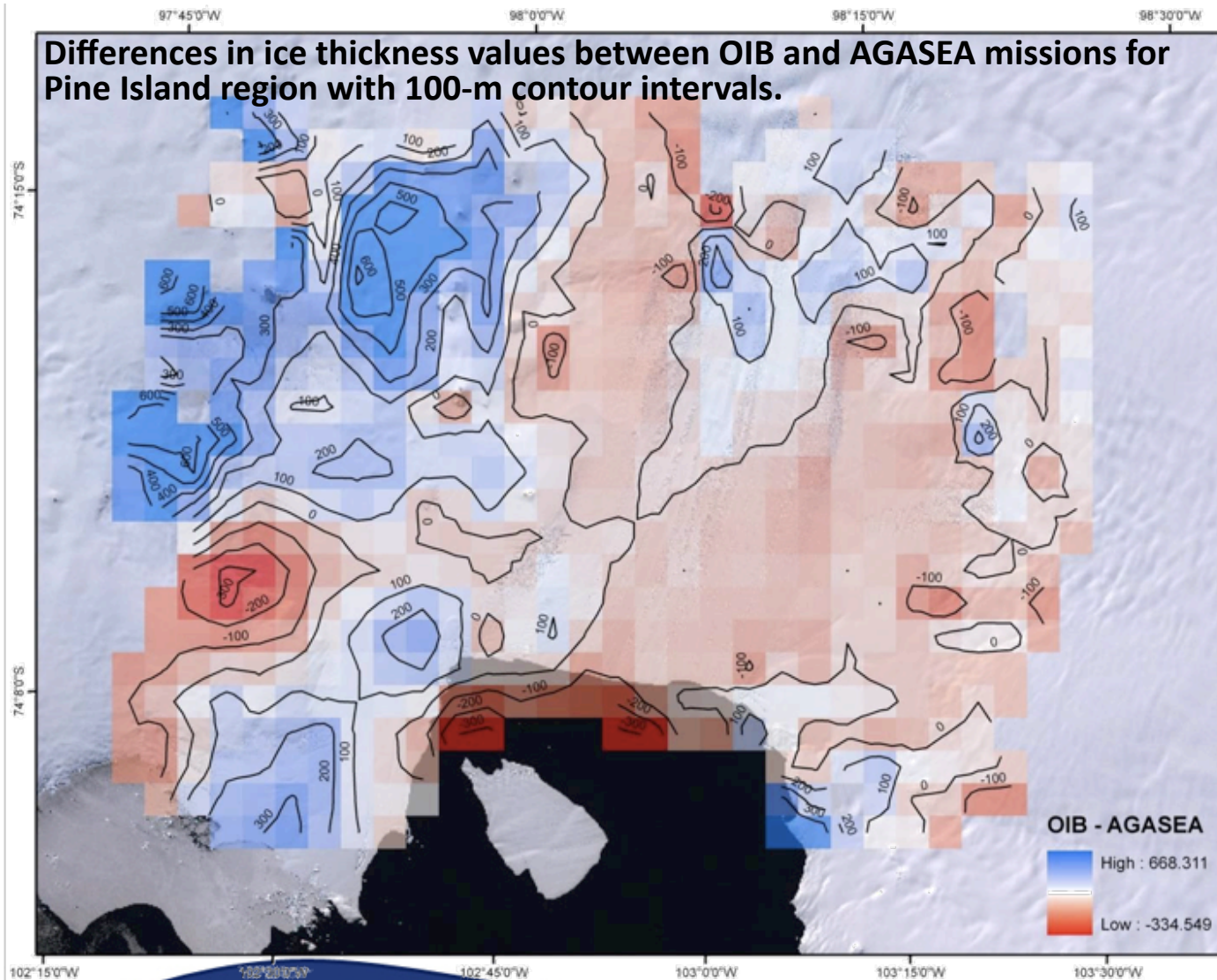
Linear IDW interpolated (10-km search radius) ice thickness DEM over Pine Island Glacier

Ice thickness



OIB ice thickness compared with AGASEA

(Holt et al., 2006)



Excellent agreement on downstream portion of ice shelf. The contours are smooth and widely spaced over the Pine Island ice tongue and glacier.

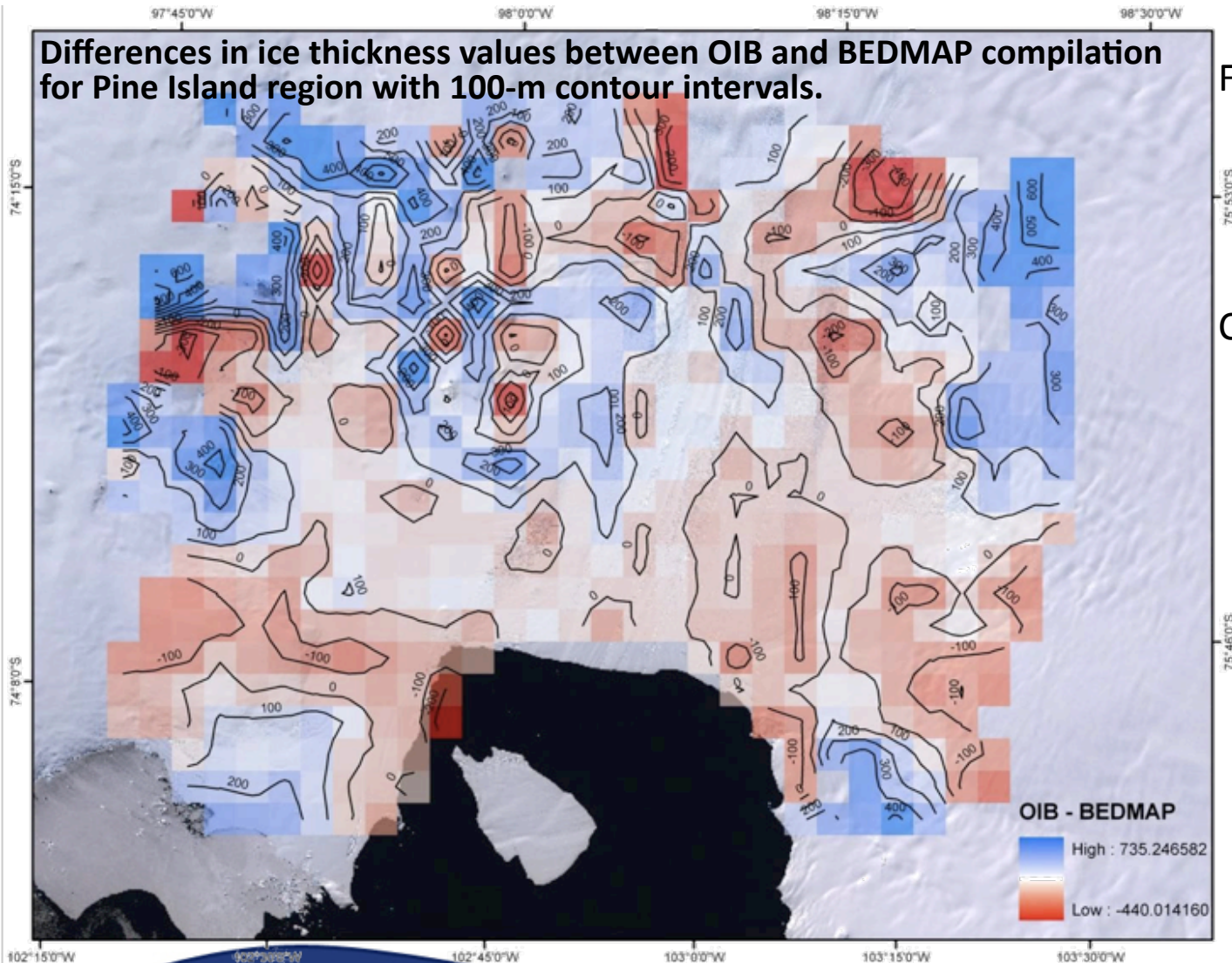
Difference in upper reaches of data set suggest possible ice thinning.



OIB ice thickness compared with BEDMAP

(Lythe et al., 2000)

Differences in ice thickness values between OIB and BEDMAP compilation for Pine Island region with 100-m contour intervals.

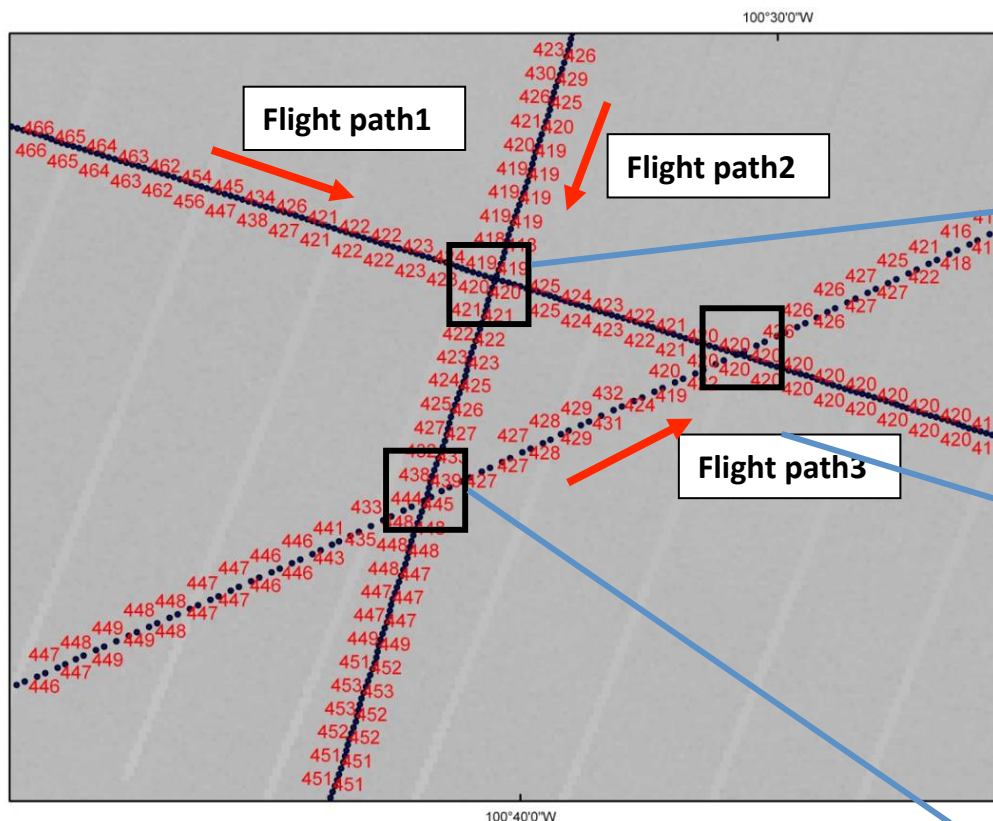


Favorable agreement over the downstream area of Pine Island Glacier.

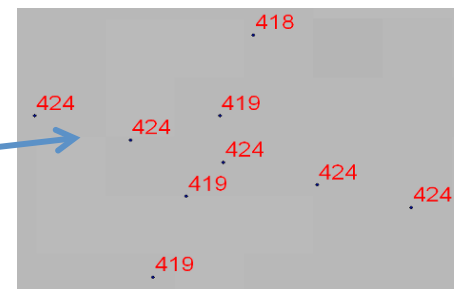
Comparison indicates possible thinning in upper reaches of the data set.



Crossover differences within OIB flight paths



Diff. between path1 and path2
is approx. 5m



Diff. between path1 and path3
is approx. 4m



Diff. between path2 and path3
is approx. 14m

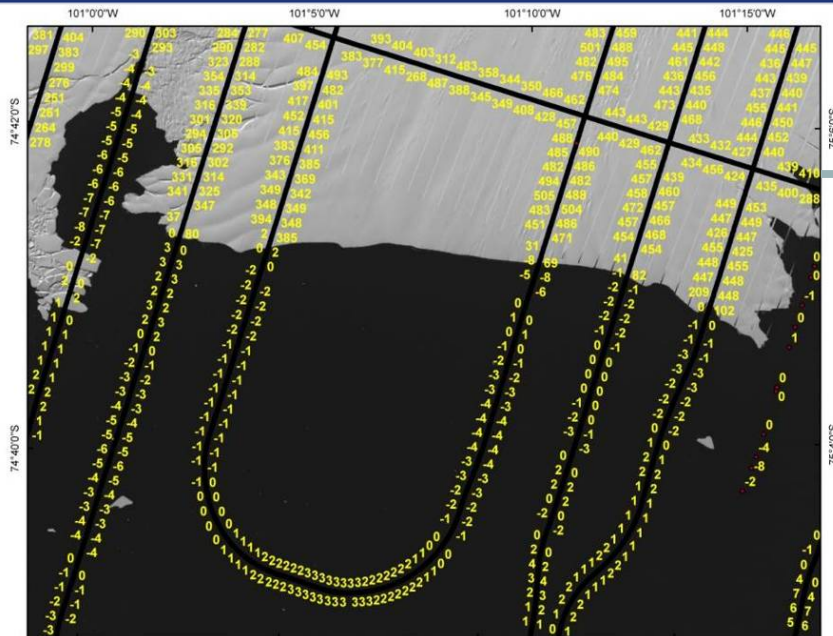


Date of flight path 1 : 20091107

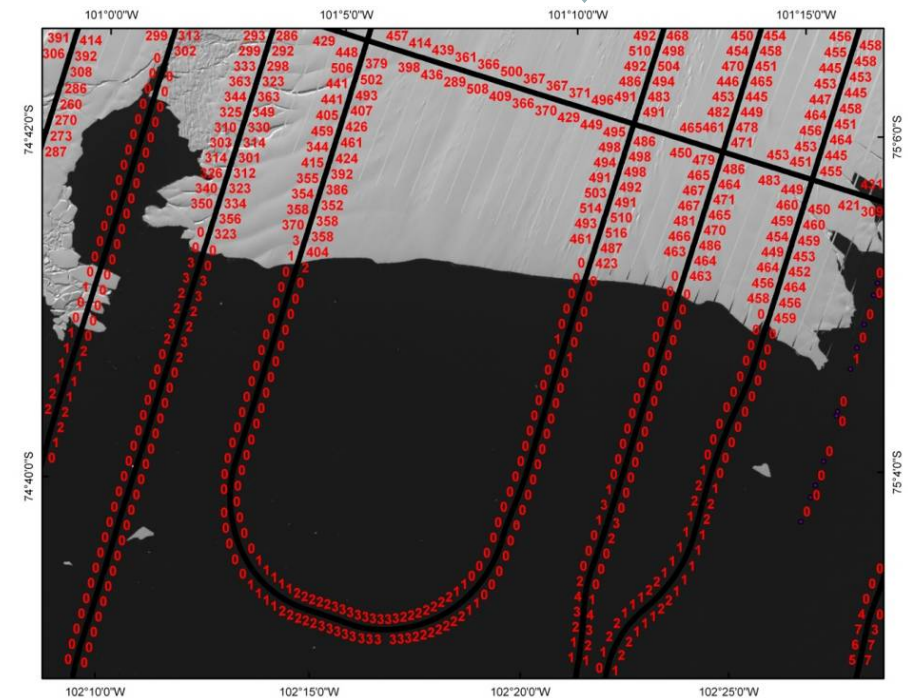
Date of flight path 2 : 20091107

Date of flight path 3 : 20091027





After correcting for cable length differences and surface/bed picking



Reasonable thickness values over the rocky outcrop area, as it remains close to zero.



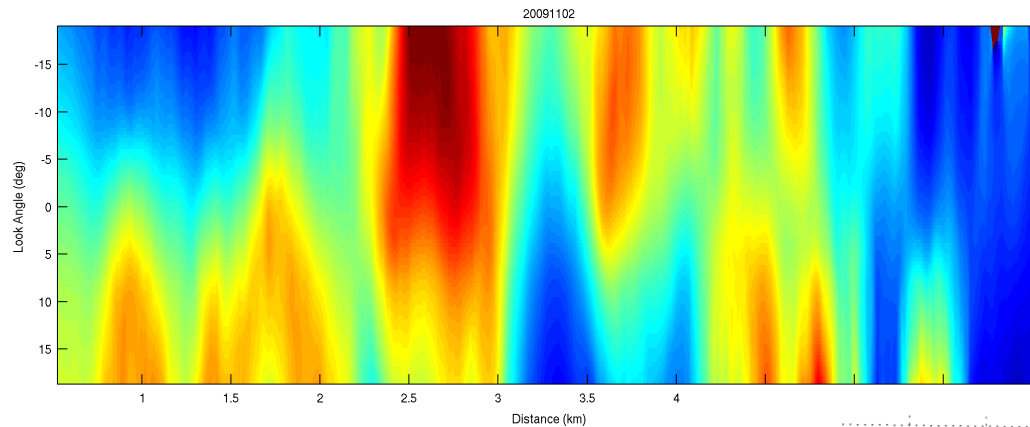
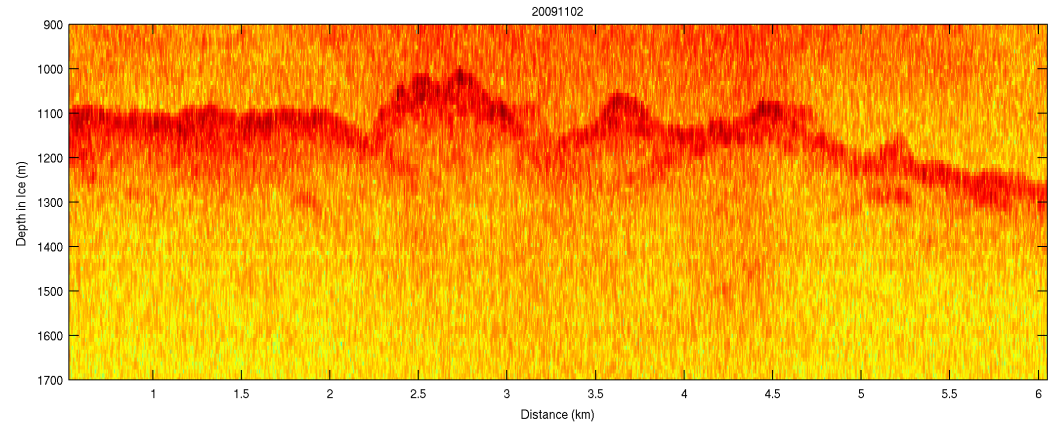
Summary

- Successfully sounded Antarctic glaciers and ice shelves in 2009
- Pine Island and Thwaites surveys show good data quality
- Identified areas for improving system performance
 - Radar operating software upgraded
 - Time-stamp latency issues identified
 - Potential for expanding bandwidth to 30 MHz
 - Power amplifier chassis upgraded to support P-3 missions
- More efficient processing algorithms developed
- Advanced processing in development that will reveal latent features



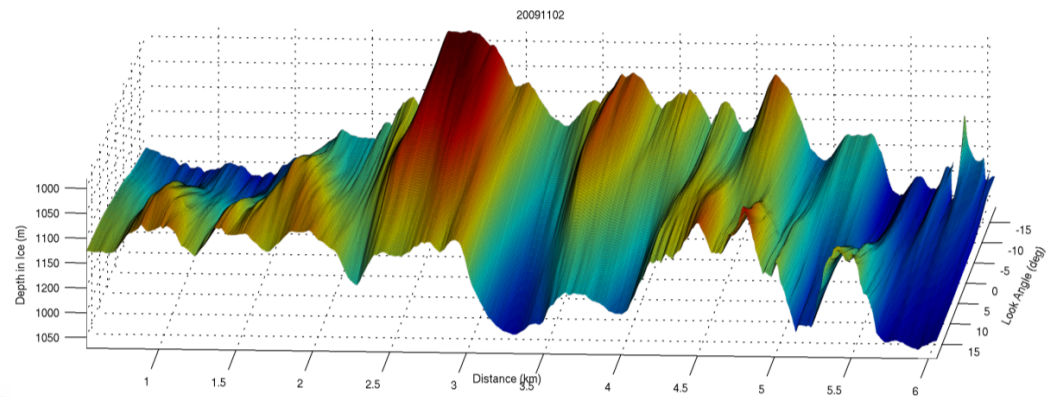
Future work

f-k migration processing data
from each channel



tomographic processing across
the 5 receive channels provides
angle-of-arrival information

project angle-of-arrival into basal
topography
(preliminary results, subject to change)





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WHERE DISCOVERIES BEGIN



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